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RATIONALIZATION OF EXHAUST SYSTEM MOUNTING BRACKETS FOR BUSES AND TRUCKS

KARTHICK. M & BELGIN PAUL. D. L

Assistant Professor, Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai, Tamil Nadu, India

ABSTRACT

Computer-aided engineering (CAE) in Product Design Cycle CAE tools are very widely used in the automotive industry. Their use has enabled the automakers to reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point, where much of the design verification is now done using computer simulations rather than too much dependency on physical prototype testing.

KEYWORDS: Computer Aided Engineering, Exhaust & Rationalization

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Original Article

1. INTRODUCTION

CAE department comes into play only after the product designing department suggests a variety of designs taking into consideration the specification provided by the marketing department. In general, there are three phases in any computer-aided engineering tasks [1]

- **Pre-Processing:** Defining the model and environmental factors to be applied to it.(typically a finite element model, but facet, voxel and thin sheet methods are also used)
- **Analysis Solver:** Usually performed on high powered computers
- **Post-Processing:** Post-processing of results (using visualization tools)

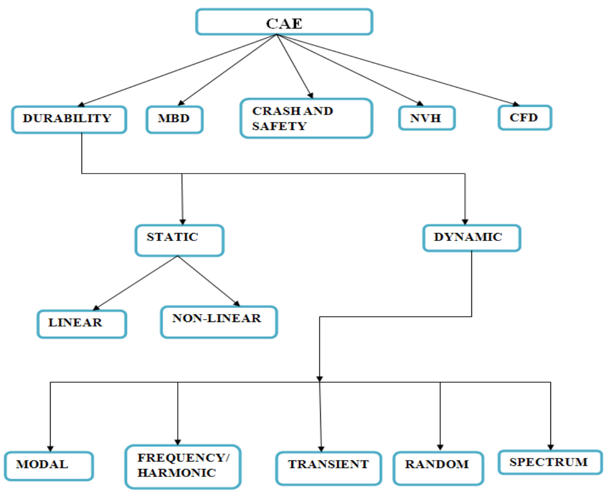


Figure 1: Role of CAE in Product Development.

Software Used

- Fluid model extraction and Meshing: ICEM-CFD, STAR CCM+
- Preprocessors and Solvers: ANSYS CFX, FLUENT, STAR CCM+
- Postprocessors: ANSYS CFX, FLUENT, STAR CCM+ [2]

1.1. General Procedure of Product Development

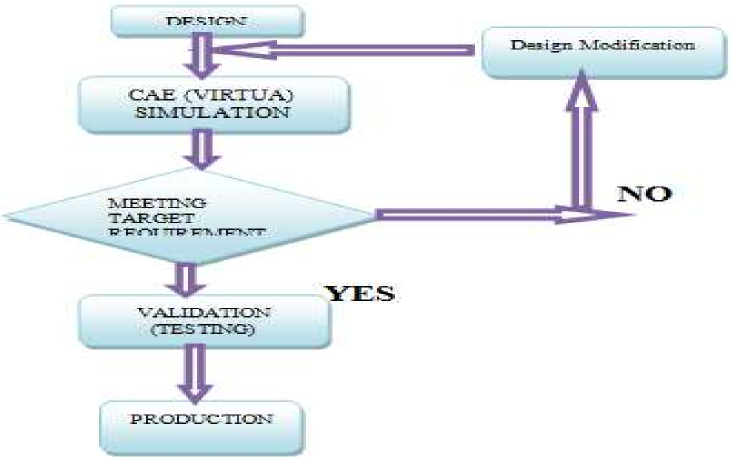


Figure 2: General Procedure of Product Development.

2. EXHAUST SYSTEM

An automotive exhaust system comprises of various devices or parts of an automotive engine, which are used for discharging burned gases created out of controlled combustion taking place inside an engine. All the burnt gases are exhaled from an engine using one or more exhaust pipes [3–5]. Figure 2 shows a typical automotive exhaust system and various components of the same. Reducing exhaust emissions-Pollution is hazardous to health and the environment. Government legislations exist in various countries of the world limiting the emission of polluting gases produced by vehicles. All vehicles need to be built to comply with these legislations and have various built-in emission control systems and devices that eliminate or greatly reduce vehicle emissions [6–10]. Various emissions from a typical automotive engine include Nitrogen Oxides (NOx), Carbon Monoxide (CO), Hydro Carbons (HC), black smoke and particulate matter and these are a function of the properties of the fuel.

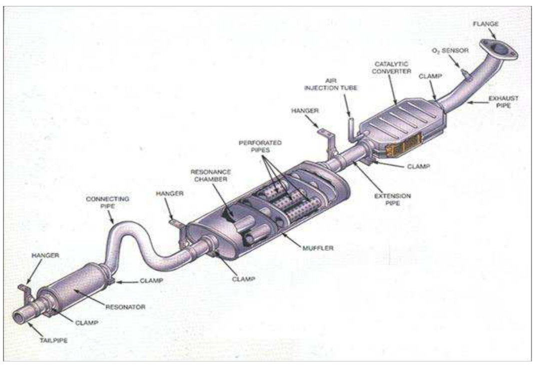


Figure 3: Schematic of an Automotive Exhaust System.

Improved Engine performance-The exhaust system directs the gases produced by the combustion process out of the engine. By ensuring a continuous smooth flow of exhaust gases out of the engine & minimum backpressure, the exhaust system improves the engine performance [11–13].

2.1 Noise Level Attenuation

Exhaust noise is a serious form of environmental pollution and government stipulations in various countries specify limits for the levels of noise created by automotive engines. For example, the legislation by Government of India passed in Aug 2005 stipulated a Pass by Noise Requirement of 78 Decibels for Engines with power greater than 75kw and less than 150kw. Mufflers are commonly used in exhaust systems to minimize the exhaust noise caused by exhaust gases. Exhaust noise is primarily created when the exhaust valves open and close. When an exhaust valve opens, it discharges the burned gases at high pressures into the exhaust pipe, which is at low pressure. This type of action creates sound waves that travel through the flowing gas, moving much faster than the gas itself (up to 1400 m.p.h.), that the muffler must silence. It generally does this by converting the sound wave energy into heat bypassing the exhaust gas and its accompanying wave pattern, through perforated chambers of varied sizes. The pressure of the gases is reduced when they pass through the muffler, so they go out of the tailpipe quietly. Passing into the perforations and reflectors within the chamber forces the sound waves to dissipate their energy. Acoustics, which is the study of sound, covers all aspects of sound production, propagation and reception whether created and received by human beings, machines or measuring instruments. A basic understanding of Acoustics is needed for gaining an insight into various parameters that affect the design and functioning of a muffler.

2.2. Mufflers can Attenuate the Noise in One of the Following Ways:

2.2.1. Passive

They are made up of reactive or resistive elements (typical automotive mufflers) that absorb, reflect or disperse sound energy to muffle the sound.

2.2.2. Active

They contain a secondary noise source to cancel out the effect of the primary noise source (mostly in head-sets). Among the passive mufflers the silencing (or muffling) chores are accomplished by one of the following methods:

2.3 Absorption

Absorptive silencers contain either fibrous or porous materials, and depending upon their absorption properties they reduce noise levels. Absorptive mufflers depend on the sound energy being converted into heat through shear in layers of fibrous or porous materials. The fraction of the sound energy absorbed by the material generally increases with frequency. Therefore, absorptive silencers are less effective at low frequencies and become more efficient as the frequency increases. Glass fiber, mineral wool and open-cell plastic foams are commonly used as the absorbing material, depending on the operating environment of the silencer.

2.4 Reflection

Reflective silencers do not contain any absorptive materials but are based on the principle of muffling of the source of the noise by an impedance mismatch, which results in reflection of noise back to the source.

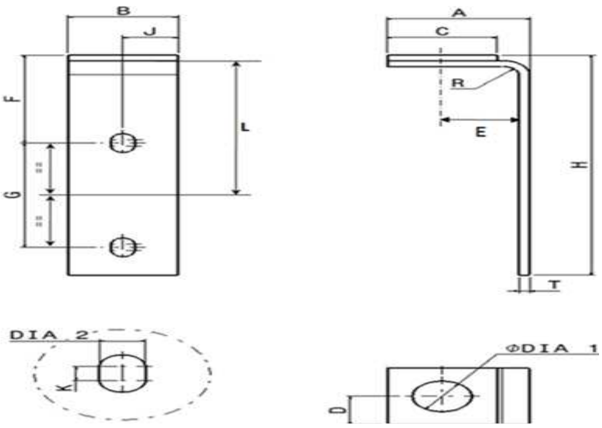


Figure 4

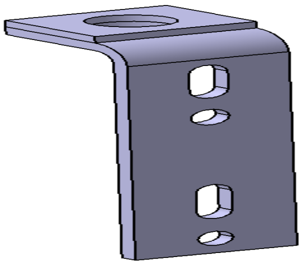


Figure 5: L Bracket Specification.

2.5 Dispersion

The noise reduction of dispersive silencers is based on the principle of diffusing high-velocity gas flow into smaller lower velocity stream(s). Some mufflers use a combination of all the above to achieve noise reduction (example Absorptive-Reflective mufflers). A basic understanding of each type of muffler is absolutely essential for an acoustical engineer for providing effective noise attenuation in fluid flow systems. The geometrical and topological details of all mounting brackets are collected and they are compared with each other for having identical geometrical details. Those parts having similarities in geometrical data are found out and considered for new design proposals. Modification in design of brackets having the same geometrical data is the way to attain improved performance of the system. Those modifications have been carried out in part modelling phase through modelling software (CATIA V5) and kept ready for further analysis.

3. DATA COLLECTION PARAMETERS

Database are created according to the geometric parameters of the mounting brackets as follows

- Horizontal length
- Breath
- C-Weld plate
- D-Diameter (D1)
- E-Distance between top of the center hole
- F- Distance between two slots
- G- Distance between the centers of the slots
- H- Overall Length of the bracket

- J-Distance in center of the slot
- K-Slot distance
- L- Distance between two slots
- R-Radius
- T-Thickness
- F-Distance between center of the hole to endplate in vertical
- G-Distance between center of the hole to endplate in horizontal

CASE: 1

There are 157 brackets in support drawing for mounting brackets. From the drawing, data are collected and identified, the similarities of the bracket and repeated part number to be eliminated from the list. Received list of 47 obsolete drawings from PLM team Consolidate the list of Remaining Brackets.

- Part 1, Part 2-The overall length of part 1 is 120mm and part 2 is 120mm. Width of part 1 is 50mm and part 2 is 50mm. thickness of the two part numbers is same 5mm. By adding slot in Part 1 eliminate a part number Part 2.
- Part 3, Part 4-length, width, height, thickness of the two parts are same. Number of holes are different and the position of the hole is different. So, two-part number is modified to one part number by making a slot in Part 4.
- Part 5, Part 6-Overall length of the part 5 is 310mm and part 6 is 311mm. Width of part 5 is 50mm and part 6 is 56mm. Number of slots is the same. By changing the position of slot in Part 5 4mm in vertical, 8mm in vertical, modify a part number Part6.
- Part 7, Part 8-By increasing the length in Part 7 (1mm), and slot hole changing position varying from 1 to 2 mm.(1mm slot varying position is not affecting any function reduce a Part 8).
- Part 9, Part 10-Over all length of part 9 is 180mm and part 10 is 180mm, width and height of the two parts are similar except height. The difference between the height in vertical plate is 7mm. if it didn't cause any hit modify the part 10.
- Part 11, Part12-By putting 4 holes in Part 1, one-part number is used in two mounting places. (But compare to Part 12, Part 12 have more in length 6mm and height 10mm).
- Part13, Part 14-By comparing the two part numbers, Part 13 more in width. (60 mm).
- Part 15, Part 16-By putting 1 hole in Part 15, one-part number is used in two mounting places. (But compare to Part 16, Part 15 have more in length 50mm.)
- Part 17, Part 18- Compared to Part 18, Part 17 have 20mm less in length, remaining parameters are same.
- Part 19, Part 20-By putting a slot in Part 19, one part number is used in two mounting places but compared to Part 20, Part 19 have more in length 6mm and width 50mm.
- Part 21, Part 22-Compared to Part 22, Part 21 have 15mm, more in height.
- Part 23, Part 24-Height of Part 23 have more 10mm compared to Part 24. Remaining all are similar.

- Part 25, Part 26-By putting two holes in Part 25, one-part number is used in two mounting places. But Part 20 has more height 50 mm compare to Part 26.
- Out of 157brackets 49 brackets are obsolete by the design team.
- Part 27, Part 28-the part number is repeated.
- Totally repeated part no in support-bracket is 11
- Finally 20-part number is reduced to 10-part number for support L bracket

3.1 Modified Bracket for Analysis

3.1.1 Existing Part 1

Overall length is 120, width is 50, height is 65, and thickness is 5. Number of holes in the vertical plate is 1and number of holes in horizontal plate is 1. Diameter of the hole is 7.

3.1.2 EXISTING PART 2

Overall length is 120mm, width is 50mm, height is 65mm, and t thickness is 5mm. Number of holes in the vertical plate is 1 and number of holes in the horizontal plate is 1. Diameter of the hole is 1.

3.1.3 Modified Bracket (Ver1)

Common similarities between these two parts are identified. The number of holes is different, but the diameter is the same. The position of the hole in part 2 and part 1 is different near the end of plate is replaced by making a slot in that place, replace two-part number and the modified part is used in two mounting places.

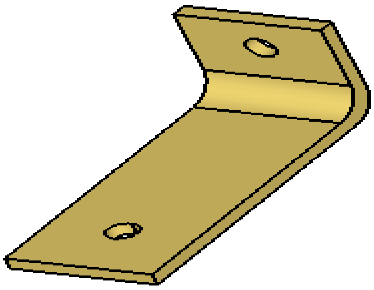


Figure 6: L Bracket Specification.

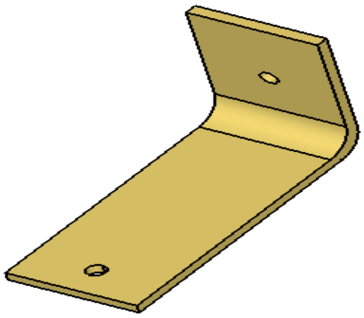


Figure 7: L Bracket Specification.

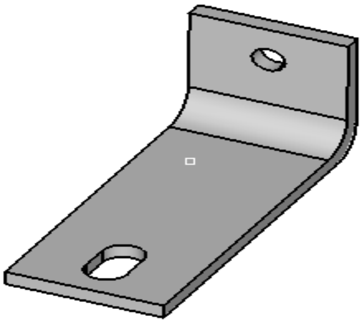


Figure 8: L Bracket Specification.

4. COMPARITIVE RESULTS FOR MOUNTING BRACKETS

4.1 Free- Free Modal Analysis

Free-free modal analysis is used to check the connectivity of the model on analysis, only 6 rigid body modes should come. If it is more than 6, it indicates that the connectivity is not proper.

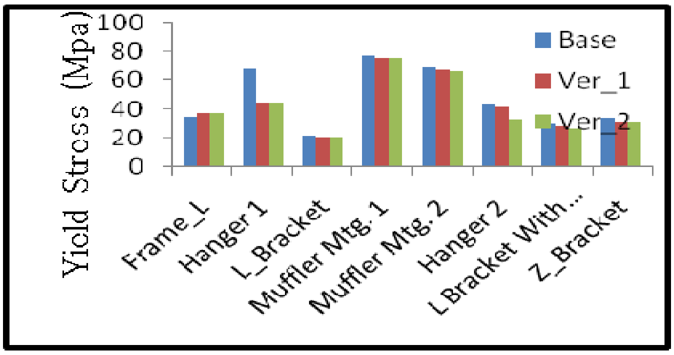
4.2 Static Analysis

Table 1: FREE-FREE Modal Analysis

Mode. No	Frequency (Hz)		
	Base	Ver1	Ver2
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	19.47	19.27	19.27
8	20.15	20.11	20.12
9	25.35	25.35	25.36
10	27.06	27.08	27.09
11	31.81	31.81	32.01
12	39.71	39.62	39.59
13	47.02	47.02	47.07
14	54.57	54.01	54.15
15	60.54	60.36	60.51

Table 2: Static Analysis Vertical 3g

Yield Stress 250 MPa						
Sl. NO	Load Case-Vertical 3G				Percentage Difference	
	Component Name	Base	Ver1	Ver2	Base vs Ver1	Base vs Ver2
1	Frame_L	34.53	36.97	36.98	**7.1**	7.1
2	Hanger 1	67.78	43.65	43.77	-35.6	-35.4
3	L_Bracket	21.25	20.36	20.36	-4.2	-4.2
4	Muffler Mtg. 1	77.99	75.9	75.89	-2.7	-2.7
5	Muffler Mtg. 2	69.37	67.58	66.25	-2.6	-4.5
6	Hanger 2	42.68	41.47	32.33	-2.8	-24.3
7	L Bracket With O_clamp	30.06	28.4	26.58	-5.5	-11.6
8	Z_Bracket	33.36	31.42	30.98	-5.8	-7.1



Bar Chart 1: Static Analysis.

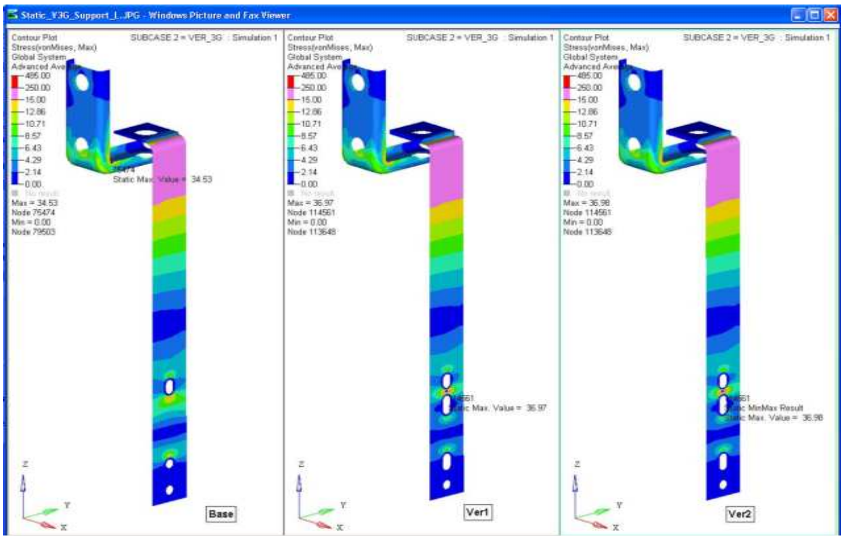


Figure 9: FE Validation Static Analysis Vertical 3g.

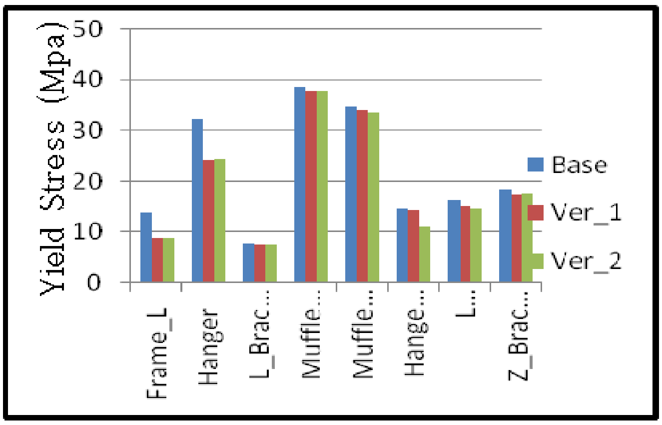
Static analysis is done to check the brackets within the material yield point

From the base model Static analysis and Ver_1 and Ver_2 analyses, it has been observed that the stress value for the existing support-L bracket is 34.53 Mpa and the modified support-L bracket is 36.97 & 36.98 Mpa. By comparing the Ver1 results with base model results, Ver1 stress value is increased by 7.1%.

4.3 Braking Analysis

Table 3: Breaking Analysis

Yield Stress 250 MPa						
Sl. No	Load Case_Braking				Percentage Difference	
	Component Name	Base	Ver1	Ver2	Base Vs Ver1	Base Vs Ver2
1	**Frame_L**	13.89	8.83	8.83	**-36.4**	-36.4
2	Hanger	32.14	24.22	24.25	-24.6	-24.5
3	L_Bracket	7.91	7.61	7.61	-3.8	-3.8
4	Muffler Mtg. 1	38.46	37.7	37.59	-2.0	-2.3
5	Muffler Mtg. 2	34.75	33.99	33.38	-2.2	-3.9
6	**Hanger 2**	14.45	14.42	10.96	-0.2	**-24.2**
7	L Bracket With O_clamp	16.23	15.07	14.66	-7.1	-9.7
8	Z_Bracket	18.43	17.3	17.56	-6.1	-4.7



Bar Chart 2: Breaking Analysis.

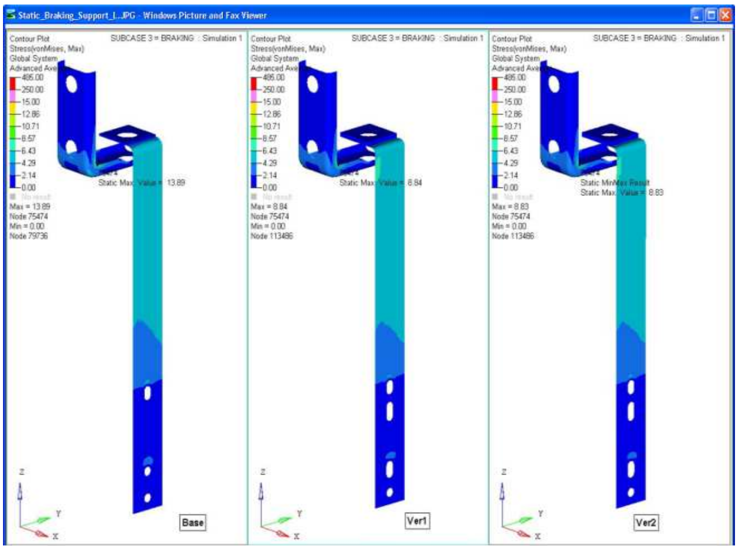


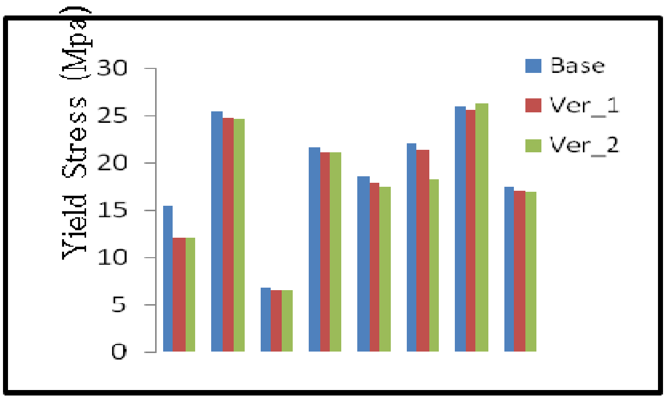
Figure 10: Fe Validation Breaking Analysis.

From the base model Static analysis and Ver_1 and Ver_2 analyses, it has been observed that the stress value for the existing support-L bracket is 13.89 Mpa and the modified support-L bracket is 8.84 & 8.83 Mpa. By comparing the Ver_1 results with base mode results, Ver_1 stress value is reduced by 36.4 %.

4.4 CORNERING-RH ANALYSIS

Table 4: Cornering-RH

Yield Stress 250 Mpa						
Sl. No	Load Case_Cornering_Rh				Percentage Difference	
	COMPONENT NAME	Base	Ver1	Ver2	Base Vs Ver1	Base Vs Ver2
1	**Frame_L**	15.4	11.99	12	**-22.1**	-22.1
2	Hanger	25.42	24.85	24.72	-2.2	-2.8
3	L-Bracket	6.8	6.48	6.48	-4.7	-4.7
4	Muffler Mtg. 1	21.65	21.07	21.06	-2.7	-2.7
5	Muffler Mtg. 2	18.49	17.83	17.52	-3.6	-5.2
6	**Hanger 2**	22.01	21.29	18.28	-3.3	**-16.9**
7	L Bracket With O-clamp	25.88	25.57	26.27	-1.2	-1.5
8	Z-Bracket	17.5	16.99	16.88	-2.9	-3.5



Bar Chart 3: Cornering-RH.

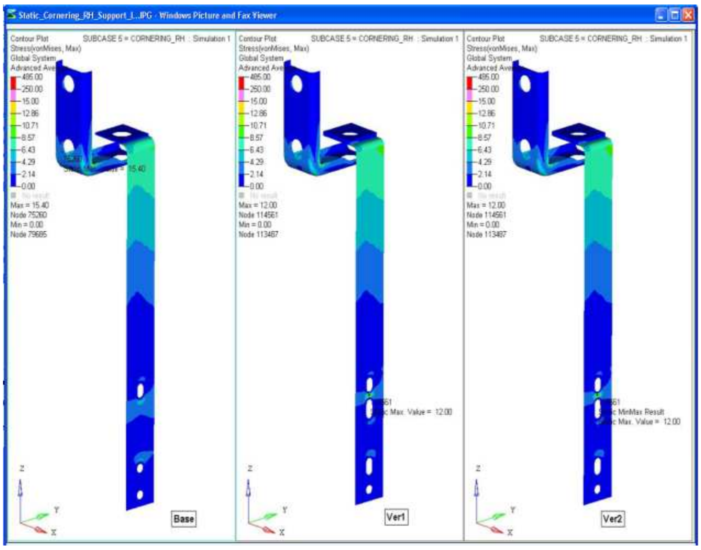


Figure 11: FE Validation Cornering-RH.

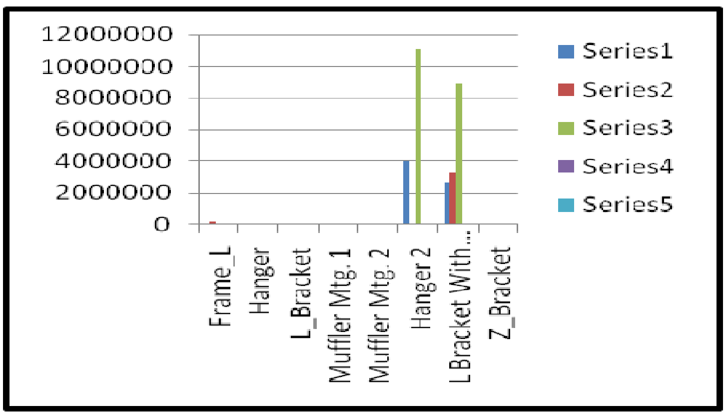
From the base model Static analysis and Ver-1 and Ver-2 analyses, it has been observed that the stress value for the existing support-L bracket is 15.40 Mpa and the modified support-L bracket is 12 & 12 M. By comparing the VER-1 results with BASE MODEL results, there is a reduction in VER-1 stress value by22.1%

4.5 Fatigue Analysis

It has been observed that the life value for base clutch housing bracket is 167 cycles and modified clutch housing bracket is 502 cycles. By comparing the VER-1 results with BASE MODEL results, VER-1 life is increased by 200.59%.

Table No 5: Fatigue Analysis

Sl. No	Component Name	Base	Ver1	Ver2	Cycle Increased for Base and Ver1	Cycle Increased for Base and Ver2
1	**Frame_L**	30100	140000	10200	**4.7**	0.3
2	Hanger	569	1500	15000	2.6	26.4
3	L_Bracket	1000	1000	1000	1.0	1.0
4	Muffler Mtg. 1	409	512	680	1.3	1.7
5	Muffler Mtg. 2	2333	5490	7210	2.4	3.1
6	**Hanger 2**	3930000	1000	1.1E+07	0.0	**2.8**
7	L Bracket With O_clamp	2640000	3270000	8880000	1.2	3.4
8	Z_Bracket	274	409	1790	1.5	6.5



Bar Chart No 4: Fatigue Analysis.

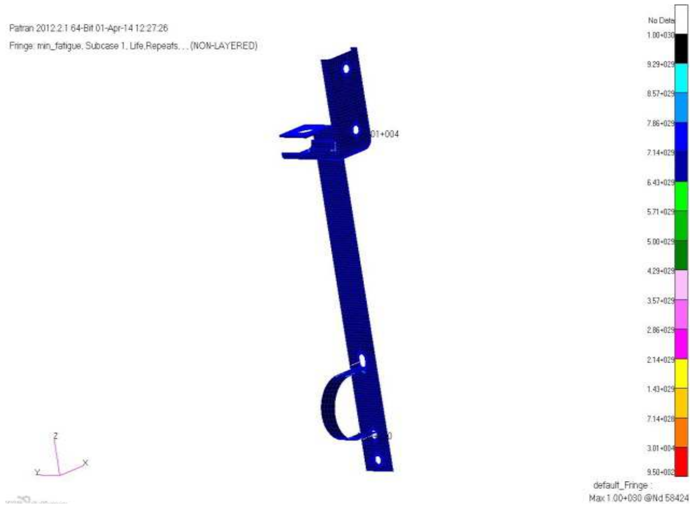


Figure 12: Fatigue Analysis-Base.

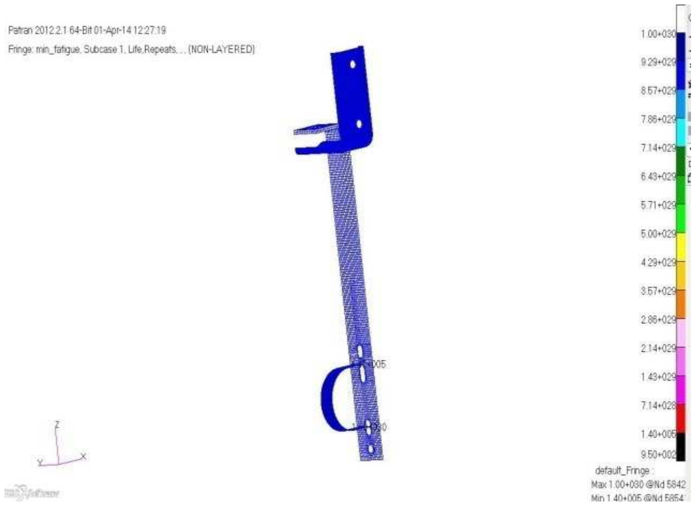


Figure 13: Fatigue Analysis-Ver-1.

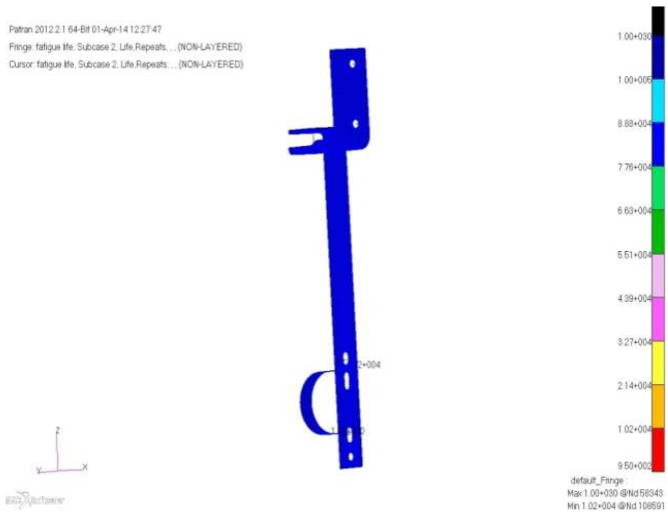


Figure 14: Fatigue Analysis-Ver-2.

5. FE VALIDATION

FE result for the existing model has been verified by hand calculation and comparison has been made.

5.1 Theoretical Calculation for Existing Model

Existing model has been considered as a cantilever beam (Free Body Diagram)

Bending moment equation= $\frac{M}{I} = \frac{F}{Y} = \frac{E}{R}$

$\sigma = \frac{My}{Ix}$

σ - Bending stress

M - Moment about the neutral axis

Y - Perpendicular distance to the neutral axis

Ix - second moment of area about the neutral axis x

B - Width of the section being analyzed

h - Depth of the section being analyzed

I = b*d^3/12

B -breath, d – depth

I = 50*5^3/12

I = 520mm^4

M = force *distance

Force = 100N

distance = 413.6mm

M = 100N*413.6mm = 41360Nmm

Y = 2.5mm

Y-displacement

Stress = 41360*2.5/520

Stress = 198.52 N/mm^2

Figure 15: Line Diagram for Bracket.

5.2 Theoretical & Practical Comparison of Stress

Table 6: Comparative Result for Theoretical and Practical

Sl. No	Component	Applied Vertical Force (N)	Fe Stress (N/Mm^2)	Hand Calculation (N/Mm^2)
1.	SUPPORT-L BRACKET	100	205.70	198.52

5.3 Fe Solution

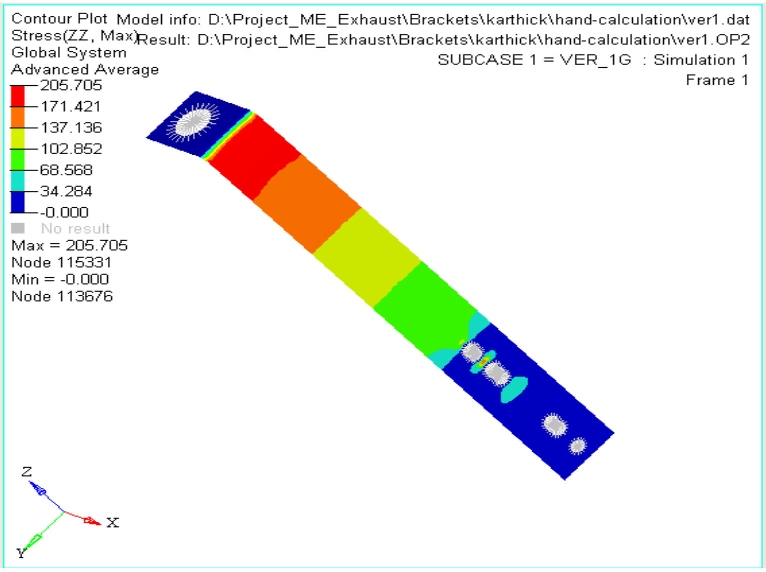


Figure 16: FE Solution.

Moderately there is slight difference between theoretical stress and practical stress. This difference arises because of the practical solver solves the problem accurately of each and every element but theoretically we calculate the whole component through derivative formula in that chance to such areas like fillet curves etc., any away theoretical stress approximately equal to piratical stress, so FE method is an acceptable one to solve other models

6. CONCLUSIONS

Rationalization has been done in Support-L brackets at first for testing. As we get better in par results, the same procedure is proposed to analyze the exhaust mounting bracket system. Analysis like free-free, static, dynamic, fatigue has been performed to the modified exhaust mounting bracket which was already rationalized. The results are derived from those analyses shows that the modified exhaust mounting bracket's performance reaches the target value in every way. Thus, it can be said that the exhaust mounting bracket system can be modified by rationalization to eliminate the unwanted parts without compromising the performance. Rationalization of the mounting bracket by (1) No longer used parts-7 part from L-bracket

(2) Duplication/repeated parts-1 in clutch housing bracket (3) Recommendation of new mounting brackets-5 from clutch housing bracket and 8 from L-bracket. One modified part is first analyzed and the results are as follows

6.1 Static Analysis

6.1.1 Vertical-3g

From the base model Static analysis and Ver-1 and Ver-2 analyses, it has been observed that the stress value for the existing support-L bracket is 34.53 Mpa and the modified support-L bracket is 36.97 & 36.98 Mpa

6.1.2 Braking

From the base model Static analysis and Ver-1 and Ver-2 analysis, it has been observed that the stress value for the existing support-L bracket is 13.89 Mpa and the modified support-L bracket is 8.84 & 8.83 Mpa

6.1.3 Cornering

From the base model Static analysis and Ver-1 and Ver-2 analyses, it has been observed that the stress value for the existing support-L bracket is 15.40 Mpa and the modified support-L bracket is 12 & 12 Mpa. From the above observation, all stress values are within the yield stress value (250Mpa), the bracket is safe under static loading conditions.

6.1.4. Fatigue analysis

The minimum fatigue life 4.7 cycle time increase compared with base-model. From this analysis result, conclude that the life of modified bracket is safe under static load condition and life is increasing in fatigue load condition.

7. FUTURE SCOPE

The present work can be extended by this analysis method and can be planned for other proposed mounting brackets and it's rationalized.

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AUTHORS PROFILE

M. Karthick Received his B.E. degree in mechanical Engineering from S.K.P engineering college, thiruvannamalai, India in 2012 and received M.E. degree in Engineering Design from S.K.P Engineering college, India, in 2014.At present he is working as an assistant professor at vel Tech Rangarajan Dr. Sagunthala R&D Institute of science and Technology, Chennai, India.

Belgin Paul D L Received his B.E. degree in mechanical Engineering from Vins Christian college of engineering, Nagercoil,India in 2011 and received M.E. degree in Computer Aided Design from University College of Engineering, Nagercoil, India, in 2014.At present he is working as an assistant professor at vel Tech Rangarajan Dr. Sagunthala R&D Institute of science and Technology, Chennai, India.